FASTRAD : A 3D CAD INTERFACE FOR RADIATION CALCULATION AND SHIELDING.

THOMAS Jean-Charles
BEUTIER Thierry
POURROUQUET Pierre
PEYRARD Pierre-François
LAVIELLE Denis
CHATRY Christian
TRAD: 17 voie l'occitane, BP47471, 31674 LABEGE CEDEX, France, fastrad@trad.fr

We present a radiation tool dedicated to the analysis and design of radiation sensitive systems. This solution has been used since 1999 in space industries. The new 3.0 release can now be applied to any radiation related field. The new format exchange module has enhanced the CAD capabilities and the range of radiation calculations has been increased thanks to the direct link created with the GEANT4 physical toolkit.

I. INTRODUCTION

The radiation hardness assurance of satellite manufacturer has been continuously improved since the last decade. The optimization of space systems in terms of either mechanical design to increase the ratio power/mass or miniaturization of electronic devices tends to increase the sensitivity of those systems to the space radiation environment. In order to mitigate the impact on radiation hardness process, the first solution is to replace the too conservative rough radiation analysis by an accurate estimate of the real radiation constraint on the system. This corresponds to the solution provided by FASTRAD for the deposited dose estimate.

In this paper we present first the Computed Aided Design (CAD) capabilities of this tool. In a second time, we focus our presentation on radiation effect analysis, first in terms of dose using the FASTRAD calculation engine and secondly in terms of particle/matter interaction using a specific interface to the GEANT4 toolkit.

II. 3D MODELING

The core of FASTRAD solution is the radiation 3D modeler. The goal of this engine is to realize a realistic model of any mechanical design including material properties. The software is dedicated to engineers who have not necessary an extensive experience in CAD applications so we have developed an easy-use interface that allows to construct a 3D model using simple functions. As shown in figure 1, the main part on the interface is devoted to the display window where the user can manipulate the geometry. The OpenCascade library included in FASTRAD provides advanced visualization capabilities like cut operations, complex shapes management, and STEP and IGES exchange format modules. The interactive window is also linked to a hierarchy tree window that can be used to handle the property of each part of the model. The main CAD capabilities of the tool are:

- Creation of Box, Sphere, Cylinder, Cone and triangular prism
- Insertion of complex 3D geometries coming from STEP or IGES format files
- Modelization tool set (clipping plane, 2D projection, measurement tool, colors, view copy,…)

Complex geometry can be easily handled and FASTRAD manages different length scales in the same model from the nanometer to 10^{24}km.

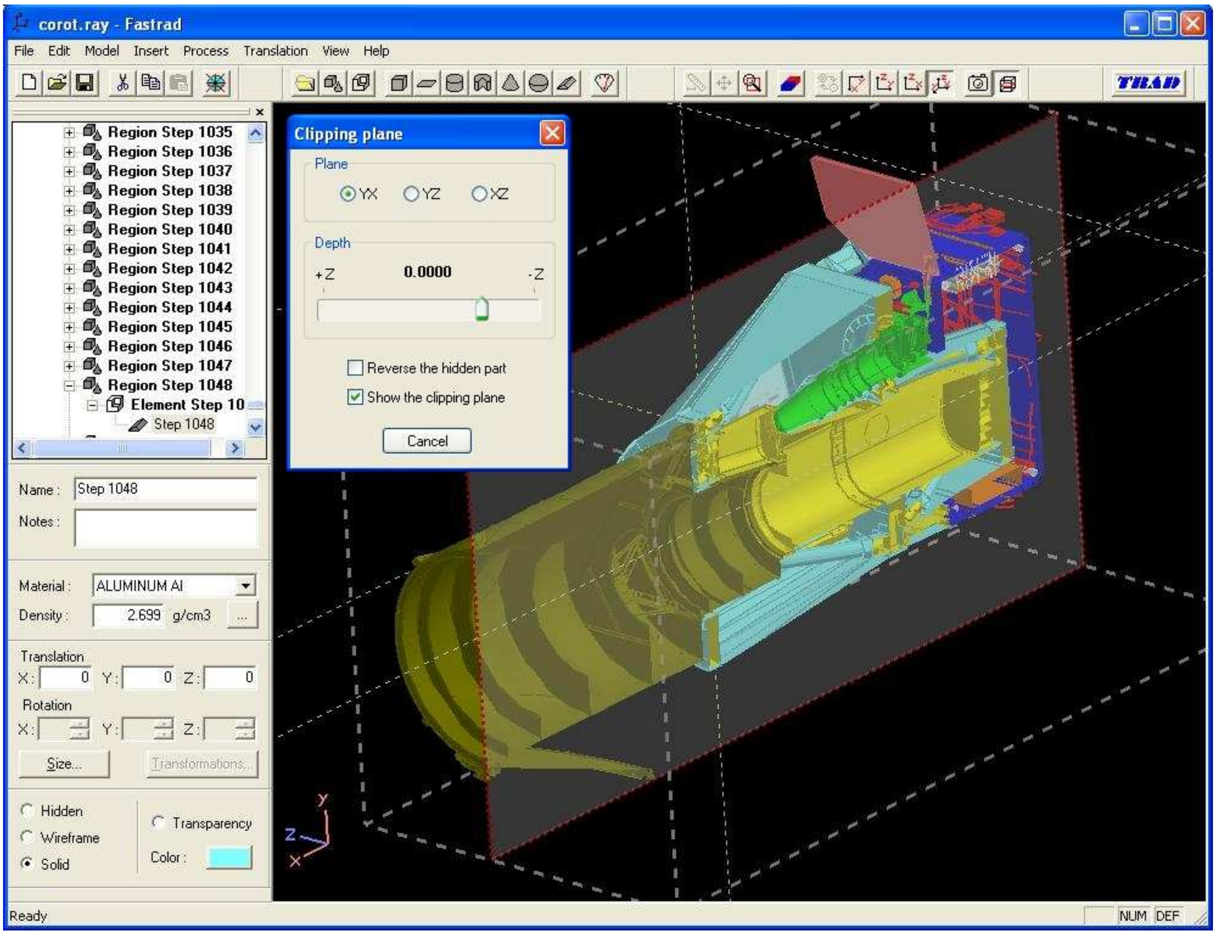

Figure 1 : Screenshot of the FASTRAD tool during a complete satellite analysis (CNES courtesy)

Additional functionalities related to the radiation applications have also been implemented. The first one is the materials module. A dedicated interface allows to set the material of each solid of the 3D model. The material properties of interest are the density of the material and the mass ratio of each element of the (compound) material. The list of predefined material can be easily extended by the user. The second functionality is the detector definition. Those detectors are used by the FASTRAD ray-tracing engine to perform sector analysis. They can be placed at any location in the model.

At any time of the 3D modeling, the user can save his model with all the information (geometry, materials, detectors) defined during the current session.

III. DOSE CALCULATION and SHIELDING

Once the 3D radiation model is done, the user can perform a deposited dose estimate using the sector analysis module of FASTRAD. This ray-tracing module combines the information coming from the radiation model with the information of the radiation environment using a Dose Depth Curve. This dose depth curve gives the deposited dose in a target material (mainly Silicon for electronic devices) behind Aluminum spherical shielding thickness. This calculation is performed for each detector placed in the 3D model. Even for complex geometry, the efficient calculation provides two kind of information :

- the 3D distribution mass around each detector
- the estimated deposited dose

Using a post-processing of those results, FASTRAD provides information about optimum shielding location using several viewing representation types. Figure 2 presents a mapping of the mass distribution viewed by one component of an electronic board. The red area indicates the critical directions in terms of shielding thickness. This helpful tool allows to optimize the size of additional shielding that can be used to decrease the received dose on the studied detector. The main advantage of this process is the short time needed to complete this task and the well defined mechanical shielding solution provided by the sector analysis post-processing.

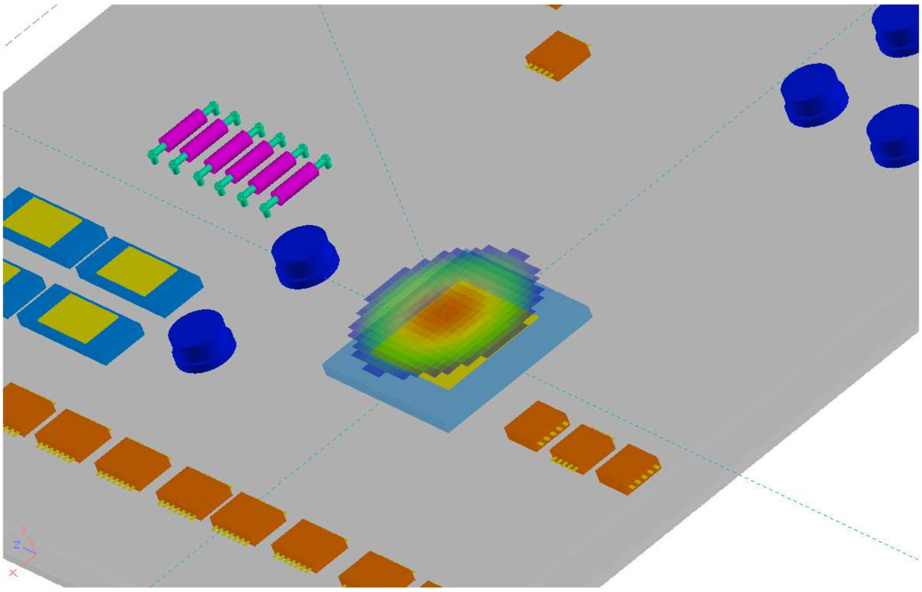

Figure 2 : Screenshot of the FASTRAD tool during a complete satellite analysis (CNES courtesy)

In this study, we have used FASTRAD to illustrate its use for two specific missions using LEO and GEO orbits, for a specific equipment which is illustrated in figure 3 below .

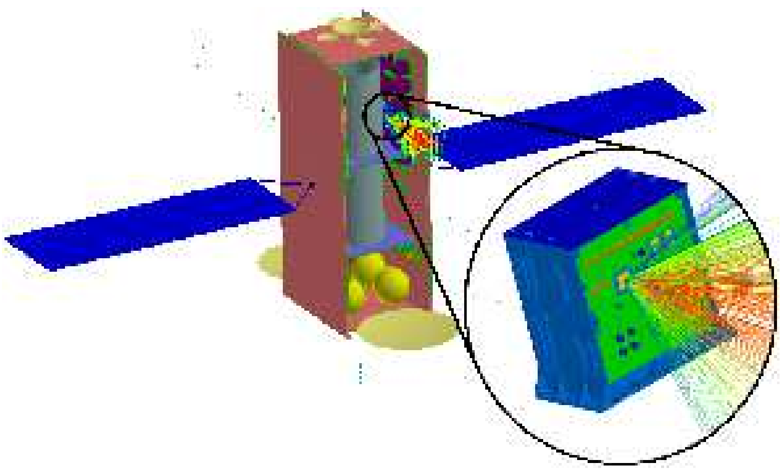

Figure 3 : FASTRAD Approach ; satellite and equipment (EREMS company courtesy) modeling

We have compared the simple 6 faces approach with FASTRAD sectorial analysis process.

For simple 6 faces approach, the following considerations are made :

- Equipment structure corresponds to a thickness of 3 mm of Al
- Component package cover being 0.25 mm of Kovar can be "converted" into 0.73 mm of Al with regards to the respective densities (7.87/2.69 x 0.25). In total, the estimated crossed thickness for the equipment is 3.73 mm of Al. Thus, the simplified approach considers an Al sphere of 3.73 mm radius surrounded by the satellite equivalent 6 faces box.

For FASTRAD, the CAD step file of the equipment is imported and the real thicknesses of the true materials is analyzed in the different directions of the total solid angle to achieve a sectorial analysis.

The results are illustrated in table 1 below

Table 1 highlights the over-estimation of the received dose (by a factor 2 in this case) by the simple approach. For GEO missions, FASTRAD would allow in this case to avoid a rad-hard procurement for the most sensitive parts, by giving a justification of a rad-tolerant approach (economic gain).

Mission type	**Deposited dose calculation (krad(Si))**	
	Simplified approach	FASTRAD approach
LEO, 800 km, 98°W, 10 years	5.4	2.8
GEO, 160° W, 18 years	35.7	10.4

Moreover, the use of FASTRAD is compliant to late design changes and/or equipement re-use. For design changes, only the new files can be simply imported and/or modified in FASTRAD. The processing of the sectorial analysis can then take place.
Also, direct calculation of shielding efficiency using the easy-use graphical interface can be performed and direct access to the masses of the different parts is possible to achieve shielding/mass increase trade-off.
For equipment re-use, only the dose-depth curve that is provided for sectorial analysis calculations has to be changed which is a single input for FASTRAD.

IV. INTERFACE TO GEANT4

GEANT4 (http://geant4.web.cern.ch/geant4/) is a particle-matter interaction toolkit maintained by a world-wide collaboration of scientists and software engineers. This C++ library contains a wide range of interaction cross section data and models together with a tracking engine of particle through a 3D geometry. The main drawback of this powerful tookit is the lack of intuitive interface to create and manage the input data necessary to perform a run.
The GEANT4 interface recently implemented in FASTRAD fill this gap by providing a tool able to create the 3D geometry, define the particle source, set the physic list and create all the resulting source files in a ready to compile GEANT4 project. This tool can be used either by young engineers who need to be driven into the GEANT4 world and who can use FASTRAD as a tutorial tool or by experts who do not want to spent time on the creation of C++ files that describes the geometry, material, and basic physics and who can use the GEANT4 project created by FASTRAD as a base that can be enhanced by specific features relative to their physical application.
In this case, the GEANT4 interface gives to FASTRAD a wide range of radiation related fields as GEANT4 is already used for space, medical, nuclear, aeronautic and military applications.

V. CONCLUSION

FASTRAD 3.0 is a new version of the existing FASTRAD solution. For space dedicated activities, FASTRAD is a very convenient and powerful tool to reduce the cycle time of mechanical design changes for shielding optimization. Also, in some cases, it can be used to justify the use of non rad-hard parts and allows to save cost and planning for some space programs equipments. Its features allow to use FASTRAD for .CAD import files and/or 3D wiewing and geometry construction.
Especially, the new GEANT4 project manager implemented in this release has considerably increased the application fields. Its intuitive and powerfull radiation CAD capabilities facilitate the engineering process for any radiation sensitive system analysis. FASTRAD is distributed exclusively by TRAD company : http://www.fastrad.net.